

The Role of Sustainable Biofuels in the Decarbonisation of Shipping

The findings of an inquiry into the Sustainability and Availability of Biofuels for Shipping

Report prepared by the Sustainable Shipping Initiative (SSI)



About this report

The Role of Sustainable Biofuels in the Decarbonisation of Shipping: The findings of an inquiry into the sustainability and availability of biofuels for shipping outlines the findings of an inquiry commissioned by the Sustainable Shipping Initiative (SSI), reflecting a stakeholder consultation process facilitated by SSI member Forum for the Future to explore the potential role (if any) of biofuels in the decarbonisation of shipping. Forum for the Future conducted the desktop literature review as well as facilitated stakeholder consultations, and put forward a draft of preliminary key findings on which the conclusions were drawn by the SSI membership.

The process was guided by SSI's Decarbonisation Working Group, whose members played an integral role throughout the consultations. It also benefited from the active engagement and contributions from speakers and participants of the seminars, webinar and Climate Week NYC event.

This report was launched at the 2019 United Nations Climate Change Conference, COP25 (Madrid, 11 December 2019).

More information on the inquiry is available at www.ssi2040.org



Moderated by Forum for the Future's Chief Executive, Dr. Sally Uren OBE, SSI's Climate Week NYC event saw a high level panel offering their views on the role of shipping in the broader energy transition; the risks and opportunities presented by biofuels to shipping; and the question of competition for biofuels with other sectors, such as aviation, among other questions. Panelists were (L-R):

- John Kornerup Bang, Head of Sustainability Strategy & Chief Climate Change Advisor, Maersk
- Lord Adair Turner, Chair, Energy Transitions Commission
- Kirsi Tikka, Independent Non-Executive Director
- Christine Weydig, Director, Office of Environmental and Energy Programs, The Port Authority of New York & New Jersey
- Gerard Ostheimer, Managing Director below50, WBCSD – World Business Council for Sustainable Development
- Manuel Pulgar Vidal, Leader of Climate & Energy Practice, WWF

Photo: Colin Clark Photo

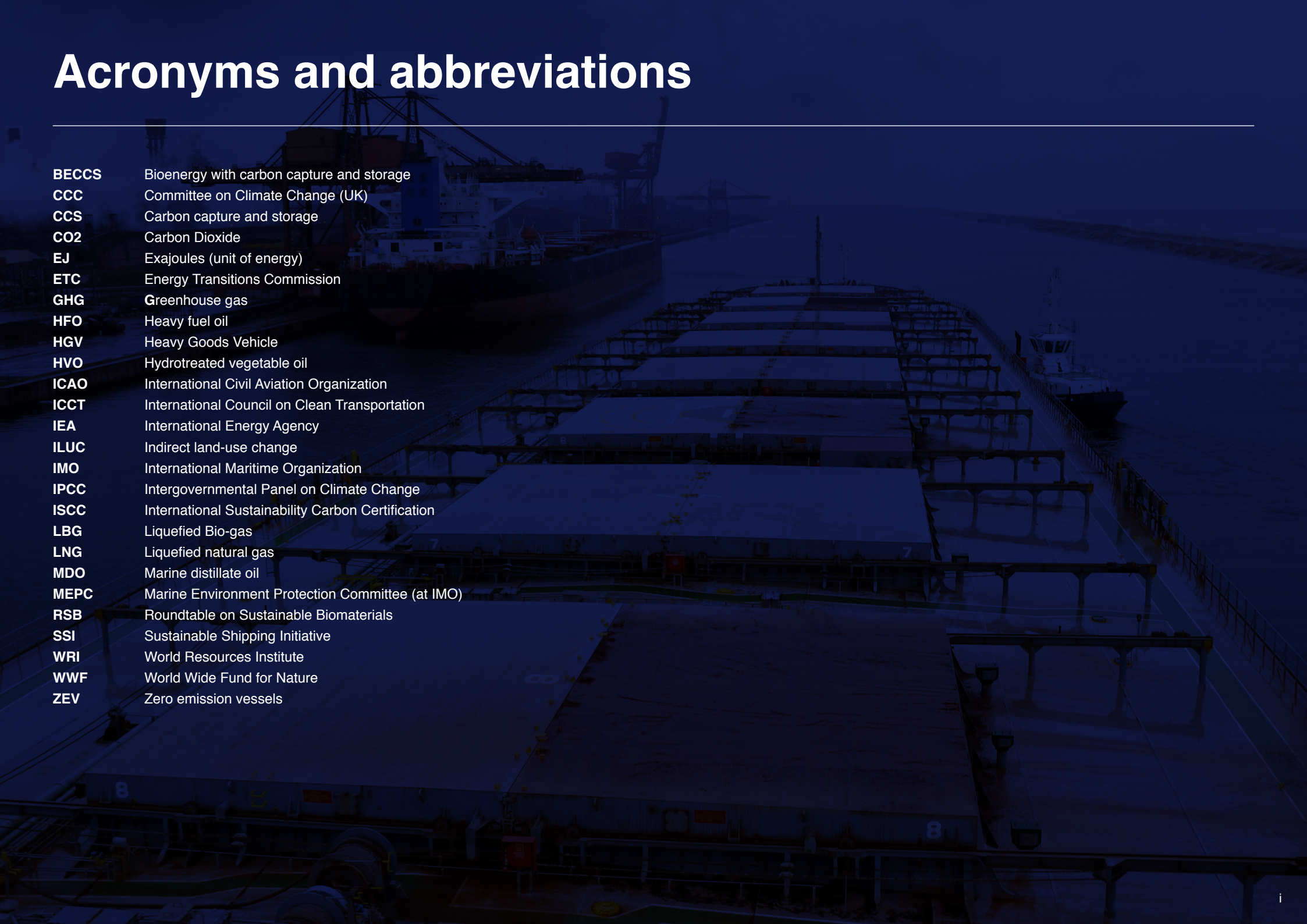
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Acronyms and abbreviations

A large cargo ship is docked in a port, viewed from a high angle. The ship's deck is visible, showing various structures and equipment. The water is calm, and the sky is overcast. The image is used as a background for the document.

BECCS	Bioenergy with carbon capture and storage
CCC	Committee on Climate Change (UK)
CCS	Carbon capture and storage
CO₂	Carbon Dioxide
EJ	Exajoules (unit of energy)
ETC	Energy Transitions Commission
GHG	Greenhouse gas
HFO	Heavy fuel oil
HGV	Heavy Goods Vehicle
HVO	Hydrotreated vegetable oil
ICAO	International Civil Aviation Organization
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
ILUC	Indirect land-use change
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ISCC	International Sustainability Carbon Certification
LBG	Liquefied Bio-gas
LNG	Liquefied natural gas
MDO	Marine distillate oil
MEPC	Marine Environment Protection Committee (at IMO)
RSB	Roundtable on Sustainable Biomaterials
SSI	Sustainable Shipping Initiative
WRI	World Resources Institute
WWF	World Wide Fund for Nature
ZEV	Zero emission vessels

Executive summary

Shipping is currently responsible for around 2 to 3%¹ of global carbon dioxide (CO₂) emissions, with virtually all 50,000 or so merchant ships burning heavy fuel oil (HFO) or marine distillate oil (MDO) or liquefied natural gas (LNG).

As the shipping industry explores how to decarbonise by mid-century, and at a minimum meet the level of ambition set out in the Initial IMO Strategy on reduction of GHG (greenhouse gas) emissions from ships (MEPC.304(72)) of reducing absolute GHG emissions by at least 50% from a 2008 baseline by 2050², zero-carbon fuels will need to be commercially available and produced from either renewable electricity, biomass or natural gas with Carbon, Capture and Storage (CCS). It is not yet clear which of the potential zero-carbon alternatives to fossil fuels has the winning combination of availability, sustainability and competitiveness.

Fuels derived from biomass, referred to as biofuels, as the primary energy source may be an attractive option for the shipping sector. Biomass can be used as a feedstock to produce alcohol fuels such as ethanol and methanol, liquified bio-gas (LBG) or bio-diesel. Such fuels could be used as drop-in or blends with minor modifications to existing engines, machinery and storage systems, which simplifies the transition from existing fossil-derived fuels. They can therefore be considered to be the most 'technologically ready' of the various zero-carbon alternatives currently under consideration for deep-sea shipping.

However, biofuels have also proven to be highly controversial, with questions raised not only about adverse sustainability impacts arising from their use, but also whether they will be available in sufficient quantities to meet the needs of different sectors.

To understand the role that biofuels could play in the decarbonisation of the maritime industry, the Sustainable Shipping Initiative (SSI) commissioned an inquiry – facilitated by sustainability non-profit Forum for the Future – into the sustainability and availability of biofuels for shipping. The inquiry methodology (Figure 1) involved a desktop literature

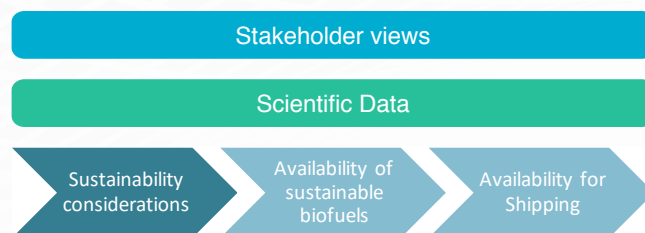


Figure 1: Approach to the inquiry

review; expert stakeholder interviews; two face-to-face stakeholder roundtables (one on sustainability issues and one on availability considerations) and a webinar; followed by a high-level panel at Climate Week New York. 109 stakeholders were consulted throughout the inquiry (Figure 2), with preliminary findings shared with additional industry stakeholders at the International Maritime Organization (IMO) during the Symposium on IMO 2020 and Alternative Fuels (17-18 October 2019) and the 6th Intersessional Working Group on the Reduction of GHG Emissions (15 November 2019); as well as the annual meeting of the Roundtable on Sustainable Biomaterials (RSB) (5-6 December 2019).

SSI members were engaged and consulted throughout the process. This report outlines the findings of this inquiry.

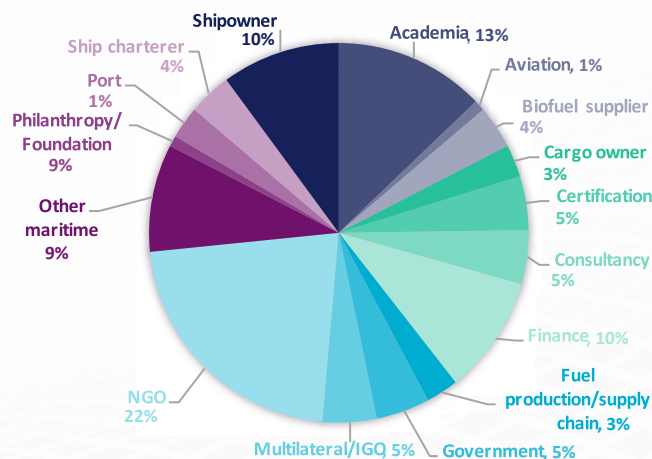


Figure 2: Stakeholder consultation

The sustainability issues surrounding biofuels

Biofuels are associated with a wide range of environmental, social and economic impacts. The inquiry revealed that the most contentious of these relate to their full life-cycle carbon credentials and how their use might have indirect impacts across global land management and food production systems.

The indirect impacts of biofuels are difficult to track and measure. This means that estimates of indirect impacts often vary greatly, and that the results of any particular study are typically questioned.

There was broad agreement found in the literature review and the stakeholder roundtables that purpose-grown crops for energy currently pose the most risk of indirect impacts, with palm and soy currently posing the greatest risks of all crops. They are therefore likely to have worse carbon credentials than other biomass feedstocks. Some studies suggest that biofuels produced from palm and soy feedstocks can be far worse in carbon terms than the fossil fuels they seek to replace.

Given these concerns, our inquiry revealed that the significant majority of the stakeholders consulted have a clear preference for any biofuels to be sourced from municipal, agricultural and/or forestry waste streams rather than purpose-grown crops. However, this preference for residues and waste streams was not unanimous: a number of stakeholders proposed that purpose-grown crop feedstocks sourced within regions with strong land governance in addition to clear carbon and biodiversity credentials would be viable to produce biofuels.

Certification schemes³ exist to evaluate the carbon and other impacts of biofuels, so that buyers and users can have confidence in their ability to provide substantial carbon savings. However, despite ongoing advances in methodologies and with the increasing recognition that bio-feedstocks require evaluation at a landscape scale, no single certification methodology currently addresses the questions and concerns around indirect and systemic impacts.

The potential availability of sustainable biofuels

A number of projections have been made regarding the future availability of sustainable biofuels. The number of variables at play in the models used to make such projections vary significantly and small changes in key assumptions can result in widely different projections. The International Energy Agency (IEA)⁴, the UK Climate Change Committee (CCC)⁵ and the Energy Transitions Commission (ETC)⁶ have all, in recent years, produced forecasts for the future potential availability of sustainable biofuels (see Figure 3).

Data on current production of sustainable biofuels is not comprehensive. The IEA states that two biofuels from waste oils (bio-diesel and hydrotreated vegetable oil (HVO) from waste oil and animal fat feedstocks) produce around 0.25EJ of biofuels, some 6-8% of total production⁷.

In the stakeholder roundtable on availability there was little consensus that feedstock availability would rise to significantly beyond 100EJ per year. Projections well beyond this, including for example the IEA's High Scenario, were considered to be practically unfeasible. In terms of the minimum amount that could be available, there was fairly broad consensus that at least 50EJ of sustainable biomass feedstock could become available per year by mid-century. Our inquiry therefore has a working assumption

of 50-100EJ as the range of available sustainable biomass; while recognising that new data could emerge indicating availability outside of this range.

Other industries are already using or have, to various degrees, stated they intend to use, biomass feedstocks to replace fossil fuels or to reduce carbon emissions in their sectors. The potential for increases in demand from these sectors needs to be considered to understand the level of certainty of estimates of the amount available to the shipping sector in the future.

Different sources of demand will drive competing pressure for the different types of bio-feedstocks, and factors for consideration include:

- whether bioenergy with CCS is scaled;
- whether ground transport decarbonises at all, and the extent it does so from biofuels rather than electrification;
- whether bio-feedstock is used to produce materials rather than fuels;
- whether construction increases the use of wood to replace concrete; and
- how much land is used for natural climate solutions such as afforestation.

It is important to understand that currently not all bio-feedstocks are useful for all these end uses: for example, it is not possible to make buildings out of biogas. There is therefore no direct substitution between all 50-100EJ of supply and all the potential demand uses.

While the details of which feedstocks could go to which industries is beyond the scope of this study, there was general consensus amongst stakeholders that aviation – with its need for kerosene or equivalent quality and energy density liquid fuels – is likely to be the closest competitor for bio-feedstocks to shipping (though existing technologies could lead to this need being fulfilled from a hydrogen feedstock instead). What remains clear is a better understanding of shipping's potential demand is needed when considering the amount of bio-feedstocks available with little competition from other sectors, and for how long.

Figure 4 compares current forecasts for demand from shipping, aviation, bioplastics as well as other potential end uses, with the working assumption that availability will be between 50-100EJ. This shows that if shipping had no competition, a substantial amount of its energy could come from bio-feedstocks on an enduring basis. However, if aviation was to significantly increase its demand, then supply starts to look like it could be short of both industries' needs, with the low estimates of demand for both equalling 78EJ and the high 145EJ.

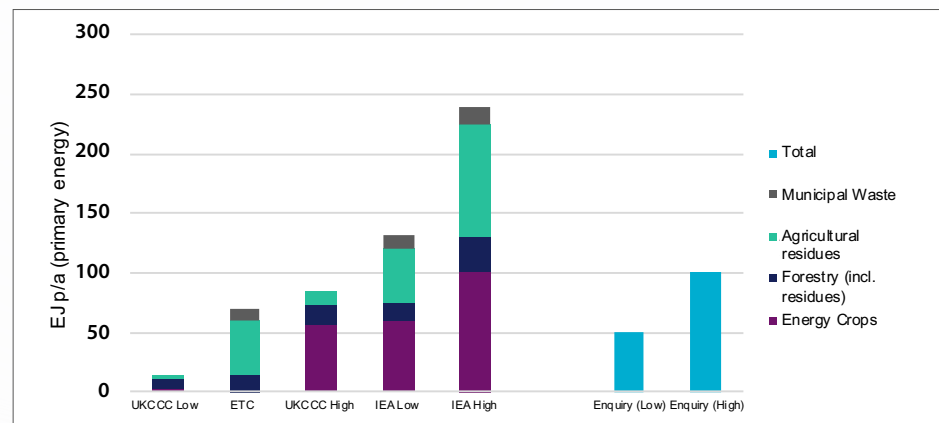


Figure 3: Forecasts for the potential future availability of sustainable biofuels by mid-century (data is in EJ per year)

Source: Figure compiled by Forum for the Future using data from UK CCC, IEA and ETC

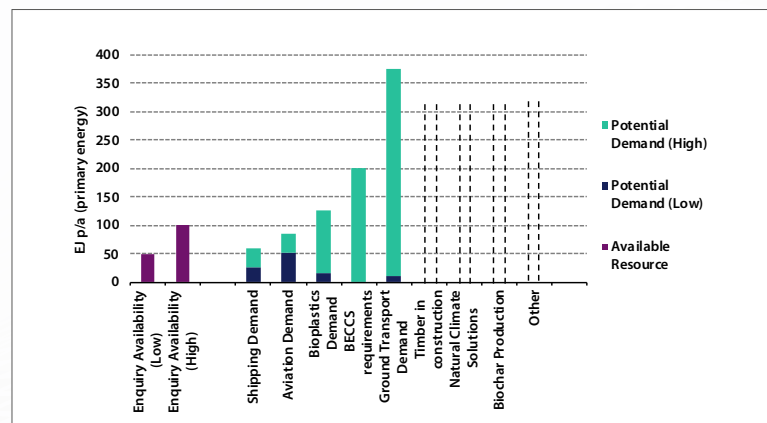


Figure 4: Projected availability of sustainable biofuel (by mid-century) compared to potential demand from a selection of industrial sectors and/or other potential uses of bio-feedstock⁸

Sources⁹: Figure compiled by Forum for the Future using data from ETC; ICCT; ICAO; IPCC; UK CCC; World Energy Council

During the stakeholder roundtables we considered how available bio-feedstock could be distributed across the economy. This could be left to market forces, but as a limited and valuable resource that could contribute in different ways to the decarbonisation of society, certain sectors could be given priority over others.



Andrew Stephens of SSI, Katharine Palmer of Lloyd's Register and Anthony Field of WWF sharing key issues emerging throughout the inquiry at the International Maritime Organization - Photo: SSI

The following factors need to be considered in answering the question of the availability of bio-feedstock for shipping:

- the consensus on the potential supply of 50-100EJ of energy from bio-feedstocks;
- the forecasted energy need for shipping of 26 to 60EJ of energy in mid-century;
- that not all bio-feedstocks, and therefore not all the potential 50-100EJ are currently feasible for use as inputs for marine fuels;
- that the price which biofuels from each feedstock can be produced is not yet clear;
- that several other sectors are considering substantial increases in their use of bio-feedstocks;
- that allocation by market forces could see sectors with more limited decarbonisation options than shipping prepared to pay more for biofuels; and
- that supply could be allocated by centralised control which could favour other sectors over shipping.

Our research on availability point to a significant – though not currently quantified – probability of supply not meeting shipping's entire energy demand. However, uncertainty around the supply assumptions, as well as the energy

demands of shipping and other sectors could lead to some plausible (though unlikely) scenarios where shipping could have 100% of its energy needs covered by biofuels.

There is also the potential that alternatives for the decarbonisation of shipping – for example fuels produced from renewable electricity or natural gas with CCS – like hydrogen and ammonia could be unfeasible due to their own sustainability, safety, availability and cost considerations. This could result in greater willingness of the shipping sector to pay for an allocation of limited biofuels.

Conclusions

1) The role of biofuels in shipping's long-term decarbonisation pathway

The supply-demand balance under current expert understanding is tight – even if shipping's demand remains within the supply range our stakeholders believed reasonable (50-100EJ). When other sectors' potential demand is factored in, the potential for shipping to meet most or all of its energy needs from biofuels is further constrained.

When asked for their views on the percentage of which shipping's energy needs would be met by biofuels in 2030 and 2050, the majority of stakeholders agreed this would fall in the 10-30% range (those responding with over 50% were outliers). Further, stakeholders anticipated that biofuel use would be higher in 2030 than 2050, implying this is a short-rather than long-term solution.

Given the ratcheting up of climate ambition across society across all industrial sectors, the pool of available bio-feedstock could be limited. Alongside this, other supply constraints raised by stakeholders were that end uses of bio-feedstocks that result in carbon being stored – i.e. in materials opposed to being released through combustion – could further limit the long-term role of biofuels in the shipping sector.

2) The potential use of biofuels to accelerate early decarbonisation

Industry stakeholders consulted in this inquiry suggested that in the short-term, biofuels could have a significant role to play to accelerate early decarbonisation action. The low end of the supply working assumption of 50EJ could more than meet all of shipping's current energy needs, and currently

only 0.25EJ of advanced biofuels are used globally. There is therefore, a potential window of opportunity for shipping to use sustainable biofuels whilst sustainable bio-feedstocks are underutilised. However, depending on the supply-demand factors, there is uncertainty on the duration of this supply, with some stakeholders suggesting it could last through much of the 2020s.

3) Scaling of sustainable biofuels

To scale the production of sustainable biofuels, market incentives are needed to provide a signal to encourage investment in the bio-economy, putting sustainability and carbon benefits front and centre. Such a signal could come in the form of IMO short-term policy measures and/or customers demanding and paying a premium for lower carbon supply chains.

Many of the stakeholders we consulted considered sustainability certification to be a pre-requisite in order to give the market confidence in biofuel use. However, not all were convinced that certification could ensure sustainability.

4) Supply-demand balance

There remains no clear consensus on whether there is sufficient sustainable biomass for shipping as well as other sectors. Current understanding suggests that a biomass-based decarbonisation pathway for shipping comes with considerable supply risks and as a consequence also poses risks related to their price.

However, there are scenarios within the working assumption range of 50-100EJ where there would be sufficient supply for shipping. The key assumptions needed to arrive at this, relate to high projections for purpose-grown energy crop use; high recovery of agriculture waste residues; road transport to electrify; and a lower to medium demand from biomaterial.

5) Risk associated with the use of biofuels

Irrespective of potential supply-demand constraints, the use of biofuel carries the additional risk of good intentions resulting in perverse outcomes, for example, increasing carbon emissions. All stakeholders who supported the use of biofuels considered certification to be a prerequisite

to ensuring the transparency and sustainability of biofuel supply chains. However, others considered current use of sustainability certification schemes to be insufficient.

One potential option for the introduction of biofuels into the shipping sector is to use bio-feedstocks from waste and residue rather than from purpose-grown energy crops, which our stakeholders deemed a lower sustainability risk.

However, if purpose-grown crops are certified using leading sustainability standards and are sourced within regions with strong land governance, carbon and biodiversity credentials, some stakeholders deemed this to have low sustainability risk while others believed it remained high.

6) The role of biofuels and innovation in the shipping industry

There is potential for the maritime industry to play a constructive role in establishing a sustainable bio-economy. Through this proactive engagement, the market for sustainable biofuels could develop to facilitate their role in the decarbonisation of shipping and in doing so, it could also support decarbonisation in other sectors. In parallel, managing the risks of a sustainable supply means continuing to innovate in zero-carbon solutions from all primary energy sources to provide a clearer picture of which options may emerge to contribute to a longer-term solution that is both available, sustainable – and competitive.

7) The need to cooperate with other sectors and players

Shipping cannot solve or manage these risks and uncertainties alone. In order to ensure that a functioning and sustainable bio-economy emerges, coordination and engagement across all interested sectors and the entire shipping value chain (ports, cargo owners, fuel producers, investors, insurers, regulators, etc) is essential. Aviation and shipping alongside other sectors all have a role to play in providing clear market signals and in ensuring that sustainability is central to the production and sourcing of biomass feedstocks.

Recommendations for further work

From this review of sustainability and availability of biofuels for shipping a clearer picture of the uncertainties and risks has emerged. This work has also illuminated key questions where additional work is needed that will advance understanding for the best routes for decarbonisation of the shipping sector:

- As Lord Adair Turner concluded at the panel event during Climate Week in New York: “A key question for shipping is how to balance the long-term decarbonisation which may well be ammonia-based with short term options such as biofuels. We need to understand better whether biofuels could be a transitional bridge to ammonia, or whether this would result in wasted investment.”
- Whether a near term scaling up of sustainable biofuels use makes the pursuit of other technologies easier or harder?
- What the level of risk is from the different crop-based feedstocks for reputational costs for the industry and unintended social, environmental and climate impacts given the various concerns over these sources of biofuels?
- Whether the use of biofuels, even those sourced from only wastes and residues, present a risk given the opposition of some stakeholders?
- When and at what scale and price could other zero-carbon alternatives become available?
- How can the shipping industry and wider value chain act to scale up the supply of sustainable biofuels?
- A deeper understanding of the likelihood around the assumptions needed to ensure enough sustainable biomass for shipping, notably the feasibility of governing purpose-grown energy crops, the feasibility of recovering substantial portions of agricultural waste residues and the likelihood of road transport to electrify.



Edmund Hughes of IMO's Marine Environment Division with seminar participants at the IMO. Photo: SSI

1. Introduction

As set out in the UN Paris Agreement on Climate Change¹⁰, nations have committed to keeping the global mean temperature increase to well below 2°C of pre-industrial levels by 2100, while making efforts to limit warming to 1.5°C. The 3rd International Maritime Organization (IMO) Greenhouse Gas (GHG) Study¹¹ estimated that shipping accounted for 2 to 3% of global carbon dioxide (CO₂) emissions between 2007 and 2012, with emissions from shipping expected to rise 50-250% by 2050 under a business-as-usual scenario.

In April 2018, the IMO adopted its Initial GHG Strategy¹², setting a target of reducing GHG emissions by at least 50% by 2050 with a strong emphasis by many countries on reducing this to 100% by 2050 wherever possible.

This provides a clear signal to the industry that the overarching solution is ending the use of fossil fuels, requiring commercially viable zero-emission vessels (ZEV) to be entering service by 2030. With virtually all 50,000 or so merchant ships burning heavy fuel oil (HFO), marine distillate oil (MDO) or liquefied natural gas (LNG), consideration will need to be given to how ships that are financed, designed and built in the 2020s can switch to a non-fossil fuel later in its operational life. Further, given that a typical ship has a lifespan of at least 20 years, investors, ship builders, ports and fuel suppliers need to know in which infrastructure they should start investing.

A number of other stakeholders are already setting more ambitious targets than those adopted by the IMO. Sweden, for example, has ruled that its vessels must be carbon neutral by 2045¹³; the UK's Clean Maritime Plan proposes that all new vessels for UK waters ordered from 2025 should be designed with zero-emission capable technologies¹⁴. Maersk has committed to be carbon neutral by 2050¹⁵. IKEA Transport & Logistics Services plans to reduce absolute GHG emissions by 70% per transport shipment by 2030¹⁶.

Launched at the UN Climate Action Summit in September 2019, the industry-led Getting to Zero Coalition¹⁷ brings together more than 100 organisations within the maritime, energy, infrastructure and finance sectors, supported by key governments and IGOs. Coalition members believe that “to reduce GHG emissions from shipping by at least 50 percent by 2050 and make the transition to full decarbonisation possible, commercially viable ZEVs must start entering the global fleet by 2030, with numbers to be radically scaled through the 2030s and 2040s.”¹⁸

Currently there is no consensus on which of the potential zero-carbon alternatives to fossil fuels – ammonia and hydrogen produced from renewable electricity or natural gas with Carbon, Capture and Storage (CCS) or biomass-derived fuels – will have the winning combination of availability, sustainability and competitiveness.

“The climate crisis is real; the climate crisis requires for us to go to zero”
- John Kornerup Bang, Chief Advisor,
Climate Change, Maersk



1.1 Why consider biofuels?

In May 2018, SSI published the report ‘Zero Emission Vessels: What needs to be done?’¹⁹ authored by Lloyd’s Register and University Maritime Advisory Services.

This report concluded that:

“advanced biofuels may represent the most economically feasible zero-emission alternative for the shipping industry. The fact that biofuels can be used in a way that very closely mirrors current technology, i.e. through internal combustion, means that associated additional costs are kept to a minimum of the fuel price itself. Under the scenarios projected in this study, these costs are within the realm of acceptability for many in the industry.”

Biofuels can be considered to be the most ‘technologically ready’ of the various alternatives being proposed for long-range shipping and are already available and being used (albeit typically in experiments and pilots^{20,21,22,23}). As such, they could hold the potential to be deployed at scale more rapidly than ammonia or hydrogen for example.

However, biofuels have also proven highly controversial, with questions raised not only about adverse sustainability impacts arising from their use, but also whether there will be sufficient availability to meet the needs of a variety of different sectors. Indeed, the Zero Emission Vessels Report went on to note that biofuels “*may not be the answer to the question of decarbonisation, due to two important, and coupled, considerations – sustainability and availability.*”

What are biofuels?

Biofuels are fuels produced using ‘recently-living’ organic feedstock (including purpose-grown energy crops, residues from agriculture and forestry, and municipal waste).

These feedstocks can be used to produce a variety of fuels with different properties and impacts.

A distinction is typically made between ‘conventional’ biofuels – made from crops that can also be used for food and feed (such as sugar, starch and vegetable oils) comprising the vast majority of biofuels currently in use – and ‘advanced’ biofuels.

The International Energy Agency (IEA) defines advanced biofuels as those “produced from non-food crop feedstocks, which are capable of delivering significant life-cycle GHG emissions savings compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts.”

Advanced biofuels represent a very small percentage of biofuels currently produced, with output expected to increase to only around 1-2% of total biofuel production by 2022.

Source: IEA, 2017²⁴

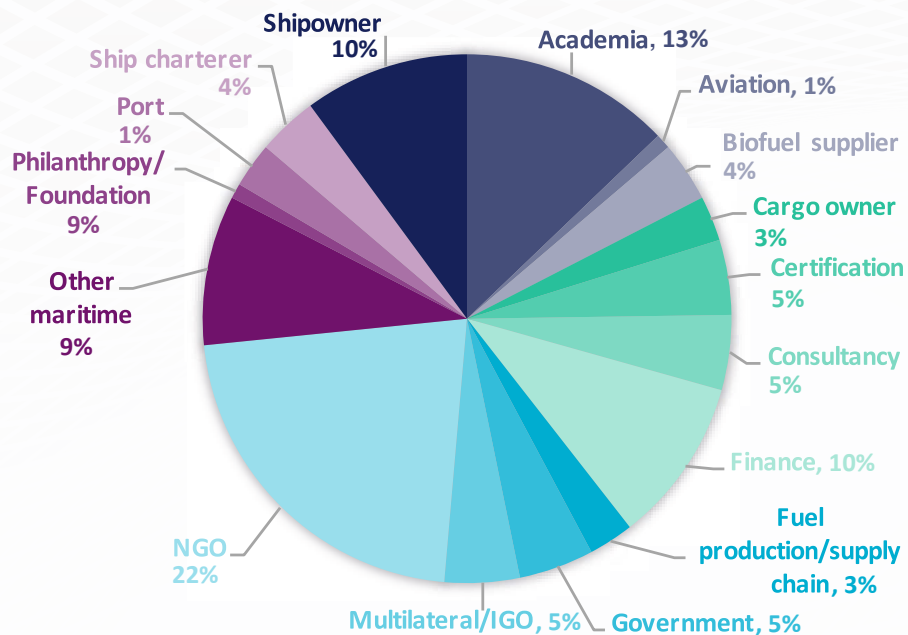


Figure 5: Stakeholders consulted during the inquiry by type

1.2 The inquiry process

In response to the report’s findings, SSI members decided to embark on a ‘deep dive’ into biofuels – under the leadership of the SSI Decarbonisation Working Group – to assess their viability for the world fleet.

This process resulted in SSI launching an inquiry and conducting a stakeholder consultation process during January-September 2019 – facilitated by sustainability non-profit Forum for the Future – into the sustainability and availability of biofuels for shipping.

Bringing together a diverse range of stakeholders encompassing actors in shipping, climate, energy among other sectors as shown in Figure 5, the inquiry sought to stimulate dialogue on decarbonisation and canvass different perspectives to answer the question:

Based on in depth stakeholder engagement on the viability, suitability and sustainability in the context of the wider system – What is the role that biofuels play, if any, in the decarbonisation of shipping?

The inquiry methodology involved a desktop literature review as well as extensive stakeholder consultations²⁵, exploring official and academic projections to identify potential risks and opportunities for the role of biofuels in shipping’s decarbonisation, whilst recognising the views emerging both from scientific research and stakeholder opinion when answering this question. SSI members were engaged and consulted throughout the process.

This report sets out the findings from this inquiry, acknowledging inevitable degrees of uncertainty and ambiguity. Section 2 outlines the key sustainability considerations; Section 3 explores the potential availability of biofuels that could be produced sustainably (and the likelihood of this becoming available to the shipping industry); and Section 4 sets out findings; and Section 5 presents conclusions and proposes recommendations for further work.

2. The Sustainability Issues Surrounding Biofuels

In identifying the main sustainability issues surrounding biofuels, the IEA's *2017 Technology Roadmap on Delivering Sustainable Bioenergy*²⁶ refers to 24 indicators identified by the Global Bioenergy Partnership, noting that all "merit analysis in sustainability assessment" (Table 1).

Environmental	Social	Economic
Environmental Life-cycle GHG emissions	Allocation and tenure of land for new bioenergy production	Productivity
Soil quality	Price and supply of a national food basket	Net energy balance
Harvest levels of wood resources	Change in income	Gross value added
Emissions of non-GHG air pollutants, including air toxics	Jobs in the bioenergy sector	Change in consumption of fossil fuels and traditional use of biomass
Water use and efficiency	Change in unpaid time spent by women and children collecting biomass	Training and re-qualification of the workforce
Water quality	Bioenergy used to expand access to modern energy services	Energy diversity
Biological diversity in the landscape	Change in mortality and burden of disease attributable to indoor smoke	Infrastructure and logistics for distribution of bioenergy
Land use and land use change related to bioenergy feedstock production	Incidence of occupational injury, illness and fatalities	Capacity and flexibility of use of bioenergy

Table 1: Sustainability issues associated with bioenergy
Source: IEA Global Bioenergy Partnership, 2017

According to the IEA, much of the uncertainty and debate around the availability of sustainable bioenergy relates to two key questions:

- What types of bioenergy lead to significant GHG emission savings, and under what conditions?
- Can sufficient bioenergy be produced under economically viable conditions without causing unacceptable environmental impacts and/or compromising current and future food supplies or prices?

Our stakeholder consultations reinforced this, finding that the most contentious concerns surrounding biofuels relate to their full life-cycle carbon credentials and how their use might have indirect impacts across global land management and food production systems. This is supported by a number of studies which challenge the widely held assumption that biofuels are inherently better in terms of carbon emissions than the fossil fuels they seek to replace.

2.1 Indirect land-use change

Indirect land-use change (iLUC) emerged strongly throughout the inquiry, generating much debate. Studies that have tried to ascertain the unintended, knock-on consequences of biofuel production on how land is used around the world have raised the greatest questions about the lifecycle emissions of certain biofuels.

Biofuel production could have a direct impact on land use if new land is cleared in order to grow the feedstocks used to create them and if the land cleared was pristine forest or other 'high-carbon stock'²⁷ land, where the carbon implications could be considerable.

When biofuels are produced on established agricultural land, this displaces other pre-existing crop production and that displaced activity may well result in new land being brought into production. These indirect impacts can also have significant carbon consequences.

Land-use change is not the only potential indirect impact of biofuel production. If farmers switch from growing food crops to bioenergy crops, biofuel production might impact

food availability and its price. Biofuel production may also divert materials that were previously used elsewhere in the economy (or which served a useful ecological function) away from their prior uses, leading to 'shortages' potentially having further knock-on impacts.

Concerns about these indirect impacts become more acute when stakeholders look to the future and imagine a world that not only has to feed more people but will have to dedicate significant areas of land to 'nature-based climate solutions'²⁸ that sequester and store carbon, all whilst withstanding the physical impacts of climate change. The World Resources Institute (WRI) highlights, that any consideration of the role of bioenergy "*must recognize the intense global competition for land, and that any dedicated use of land for bioenergy inherently comes at the cost of not using that land for food, feed, or sustained carbon storage.*"²⁹

These impacts are exceptionally difficult to track and measure, are inherently dynamic and dependent upon a large number of socio-economic variables. Whilst our inquiry acknowledged that direct impacts exist, the specifics are often lost in the complexities of global markets, local politics and culture.

This complexity is recognised by the Intergovernmental Panel on Climate Change (IPCC) in its August 2019 Special Report on Climate Change and Land³⁰:

"The production and use of biomass for bioenergy can have co-benefits, adverse side effects, and risks for land degradation, food insecurity, GHG emissions and other environmental and sustainable development goals... These impacts are context specific and depend on the scale of deployment, initial land use, land type, bioenergy feedstock, initial carbon stocks, climatic region and management regime, and other land-demanding response options can have a similar range of consequences."

The UK Committee on Climate Change (CCC) puts it more directly "...estimating iLUC effects remains complex, contested, and [has] wide uncertainties."³¹

This explains why estimates of indirect impacts often vary greatly, and that the results of any particular study are typically questioned.

Acknowledging these uncertainties, there was fair agreement amongst the stakeholders consulted as to which bio-feedstocks currently pose the most risk of indirect land-use impacts and have the greatest risk in carbon terms compared to fossil fuels.

2.2 GHG emissions

Following the introduction of regional targets that encouraged the use of biofuels across the transport sector, the European Union commissioned research in 2015 which found that once indirect land-use impacts were considered, carbon emissions from palm, rapeseed and soy-based biodiesel were often higher than the fossil fuels they replaced³². Recent research by Cerulogy (January 2019) reinforces this noting that both palm and soy “are associated with ‘significant’ conversion of high carbon stock land, and should therefore be categorised as high iLUC-risk.”³³

Research conducted by the International Council on Clean Transportation’s (ICCT)³⁴ confirms that biofuels derived from both palm and soy could result in higher emissions than fossil fuels as shown in Figure 6.

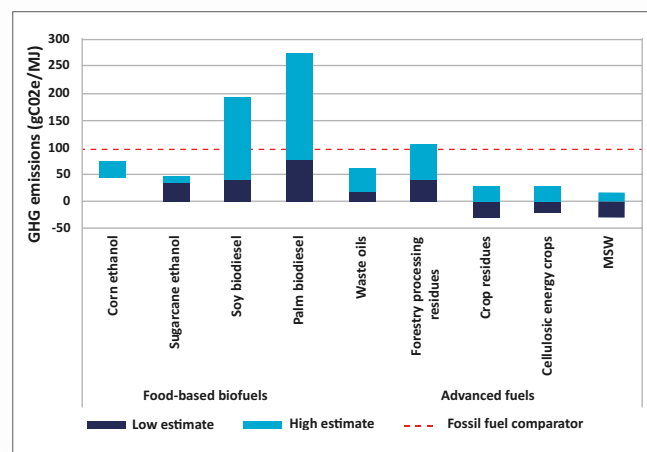


Figure 6: Comparison of lifecycle GHG emissions associated with different biofuels (MSW refers to Municipal Solid Waste)

Source: ICCT, 2019

This evidence notes the lack of effective land governance, the need for evaluation and certification systems that look beyond specific feedstocks to adopt a more contextual approach. The IEA recommends that the certification of biomass fuel supply chains be “based on the actual GHG performance of specific routes from feedstock to energy, rather than a classification based on feedstocks or technologies.”³⁵

WWF South Africa cautions that it is neither possible nor advisable to generalise the emissions reduction potential of biofuels; rather, they call for “every single supply chain should be subject to a rigorous life-cycle assessment process with adequate system boundaries to determine its value in delivering real, significant and measurable emissions reductions.”³⁶

The above evidence is supported by a growing number of stakeholders, including those we consulted.

This inquiry found that rigorous life-cycle assessments are not consistently applied across all bio-feedstock supply chains, and current global land governance systems do not necessarily guarantee the protection of ‘high-carbon stock’ land. Therefore, when asking what the role of biofuels is, for shipping industry, raises the need to be aware that any sourcing of soy or palm-based biofuel currently runs a high risk of indirect land-use change and stakeholder reputational risks.

Given that the potential for indirect and substitution impacts exists across all purpose-grown energy crops, a clear preference from stakeholders for any biofuels to be sourced from municipal, agricultural and/or forestry waste streams emerged during our inquiry.

This preference is shared by the Energy Transitions Commission (ETC):

*“It is essential... that biofuels are sourced in a truly sustainable way, which should ideally not involve the significant use of plants which compete with food production but be based primarily or entirely on waste streams (municipal, agricultural or forestry waste) or lignocellulosic sources.”*³⁷

However, this view is not universal, and a number of stakeholders were comfortable with purpose-grown (or diverted food) feedstocks being used to produce biofuels provided these are sourced within regions with strong land governance, carbon and biodiversity credentials. While recognising the potential for conflict between natural habitat protection, food production, afforestation and the production of energy crops, the IPCC also recognises that “the land that we are already using could feed the world in a changing climate and provide biomass for renewable energy” although caveats this with the condition that this “would require early, far-reaching action.”³⁸

One study published by WWF South Africa in January 2019³⁹ found that biofuel production can fit within a land management system that not only provides food but also protects high-value biodiversity. This study explored the current and future potential of bio-feedstock production in sub-Saharan Africa using the sustainability criteria of the Roundtable on Sustainable Biomaterials (RSB) Standard.⁴⁰

The study found that around; 0.8 million km² in Sub-Saharan Africa is suitable for bio-feedstock production, potentially yielding around 7EJ of energy if dedicated to biofuel production, creating 10- 20 million jobs in the farming sector. Assuming that future demographic change and improved diets will require some of this land to be converted to food production, WWF project that 4EJ of biofuel could be produced sustainably in Sub-Saharan Africa in 2050.

Beyond such systemic studies, a number of stakeholders also stressed that energy crop production can sometimes support, rather than directly compete with food and feed production. A farmer might be able to introduce an energy crop into an agricultural rotation, for example, and thus its production could potentially help with soil quality and pest/disease prevention. Such nuances are often lost from decisions about whether purpose-grown energy crops are a good or bad thing.

2.3 Sustainability assurance

These examples suggest that purpose-grown energy crop feedstocks could still be considered as sustainable in the view of stakeholder opinion and identify the need to ensure that these are sourced from regions with strong land governance, carbon and biodiversity credentials which could pose practical problems in the near-term.

There are ongoing improvements in certification methodologies and approaches and an increasing recognition that the sustainability of feedstocks must be evaluated at a regional or landscape-scale. However, it remains difficult to address such nuances, or wider indirect and systemic impacts, within certification schemes.

The certification schemes that participated in our inquiry are quite aware of this landscape-scale challenge, however, and are confident that they are evolving appropriately. Stakeholders consulted through this inquiry pointed to a principles-based approach – such as that embraced by RSB – offers the greatest potential.

Currently, no single standard addresses and answers all the sustainability questions raised by all different stakeholders. A number of stakeholders engaged in our inquiry raised concerns that any certification scheme adequately addresses the full suite of indirect emissions and impacts associated with purpose-grown crops for fuel, which continues to present risk for end-users of certified biofuels.

For purpose-grown biofuels to play a part in shipping's future, effective regional land governance systems are a key consideration.

Are biofuels really carbon-neutral?

Some stakeholders challenge the carbon credentials of biofuels as well as the assumption that bioenergy is inherently carbon neutral.

While the burning of biofuel emits CO₂, these emissions are typically excluded from carbon accounting on the basis that this release is matched and offset by the CO₂ absorbed by the plants growing the biomass feedstock. The World Resources Institute (WRI) suggests that if plant growth was going to happen, which would likely be the case in both cultivated and natural systems, then diverting plants to bioenergy production does not actually remove any additional carbon from the atmosphere (which would have to happen for the offsetting assumption to be valid).

Such concerns about the carbon neutrality of biofuels are supported by a 2016 study that found that the net carbon uptake on associated cropland during the 2008–2013 period of US biofuel expansion was only sufficient to offset 37% of the biofuel-related CO₂ emissions over the same timeframe.

Factoring this into the carbon accounting methodologies used to evaluate biofuels, would substantially reduce the carbon credentials of purpose-grown bio-feedstocks.

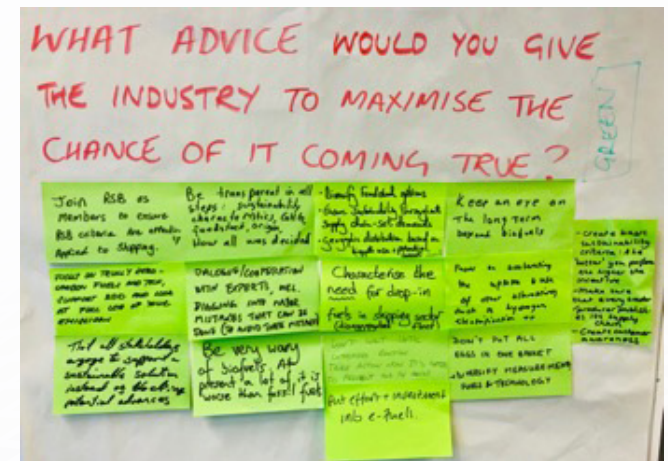
Sources: DeCicco, 2016; WRI

***“We need a systemic vision.
It is not just about biofuels.”***

*- Manuel Pulgar Vidal, Leader of
Climate & Energy Practice, WWF*



Photo: Colin Clark Photo



Seminar participants offered their advice to the shipping industry on the sustainability of biofuels. Photo: SSI

3. The Potential Availability of Sustainable Biofuels

According to the IEA, primary energy supply from biomass is around 53 exajoules (EJ) per year, reduced to around 25EJ if traditional uses of biomass are excluded.⁴¹ Biofuels, which are currently used primarily in road transportation (comprising around 4% [by energy] of world road transport fuel in 2016) only account for around 3.6EJ of this total.⁴² Data on current production of sustainable biofuels is uncomprehensive. The IEA state that two biofuels from waste oils (bio-diesel and hydrotreated vegetable oil (HVO) from waste oil and animal fat feedstocks) produced around 0.25EJ of biofuels, some 6-8% of total 2018 production.⁴³

For comparison:

- Road transportation's total current energy demand is 82.5EJ.⁴⁴
- Shipping's current demand is around 10EJ per year (and is projected to grow to some 13EJ per year by 2050).⁴⁵
- Aviation's current demand is approximately 10EJ per year (and the highest projections for future demand see this rise to as much as 85EJ per year by 2050).⁴⁶

In addition to these transportation sectors, a range of other sectors including construction through to plastics are also looking to use bio-feedstocks as a means to reduce fossil fuel. The UK CCC suggests that the global technical potential of bio-based plastics alone could be as high as 110EJ in 2050.

3.1 How much sustainable biofuel might become available?

Projecting how global climate ambition and policy, land governance options, technology trends, diets and other factors will change over the next few decades in order to determine how much land or waste might become available for sustainable biofuel production is difficult, particularly given the challenges with measuring the indirect land-use impacts. A range of variables are used in the models to forecast demand and small changes in key assumptions can result in widely different forecasts.

High projections of the future availability of biofuels are typically based on a number of optimistic assumptions: from the highest availability of land for feedstock cultivation and the highest residue capture rates; through to the presence of strong market and regulatory support for bioenergy. Low projections tend to assume little supportive structures towards bioenergy.

Despite this variation, there is a degree of consistency across a number of studies. Research conducted in August 2018⁴⁷ noted, for example, that "there is high agreement from previous literature that 100EJ yr⁻¹ of bioenergy could be produced sustainably, and moderate agreement that this can increase to 100–300EJ yr⁻¹."

	Total Availability	Energy Crops	Municipal Waste	Agricultural Residues	Forestry (including residues)
UK CCC (2050)	14-84	4-57	n/a	3-12	7-15
IEA (2060)	131-240	60-100	10-15	46-95	15-30
Energy Transition Commission (mid-Century)	70	excluded	10	45	15

Table 2: Projections of future availability of sustainable biofuels (data is in EJ per year)

Source: Table compiled by Forum for the Future using data from UK CCC, IEA and ETC

The IEA⁴⁸, the UK CCC⁴⁹ and the ETC⁵⁰ have all, in recent years, produced projections for future availability of sustainable biofuels; however, the results are not directly cross-comparable. The UK CCC focuses on the availability of globally tradeable bio-feedstock; whereas the IEA quantifies total availability. UK CCC data looks forward to 2050, whereas IEA numbers are for 2060. The ETC embraces the IEA's analysis, but then applies additional screens.

Table 2 compares these studies, illustrating the differences as well as where potential risks and uncertainties lie.

The UK CCC's low-end projection sees the global tradable bioenergy resource in 2050 fall to around half that of today.

This results from a future scenario of a fragmented world with less international cooperation than today and low levels of international trade and investment, therefore high global population growth, high food demand, meat intensive diets and low levels of innovation mean that much more land is required in 2050 for agriculture and very little land is available for energy crops.

In comparison, the high-end projection reflects an inter-connected green growth, investment and innovation' scenario in which "increasing levels of market and infrastructure development" and "strong global governance" both facilitate greater availability of sustainable biomass, as well as ensuring only sustainable biomass is produced and traded.

And low global population growth and a shift to less meat-intensive diets means less land is needed for food in 2050 compared to today.



Marie Hubatova, Environmental Defense Fund; Andrew Welfle, University of Manchester; Carlo Raucci, UMAS; Katharine Palmer, Lloyds Register; Andrew Stephens, SSI; John Kornerup Bang, Maersk; Iain Watt, Forum for the Future; Uwe Fritsche, IINAS; Katja Oehmichen, DBF. Photo: SS

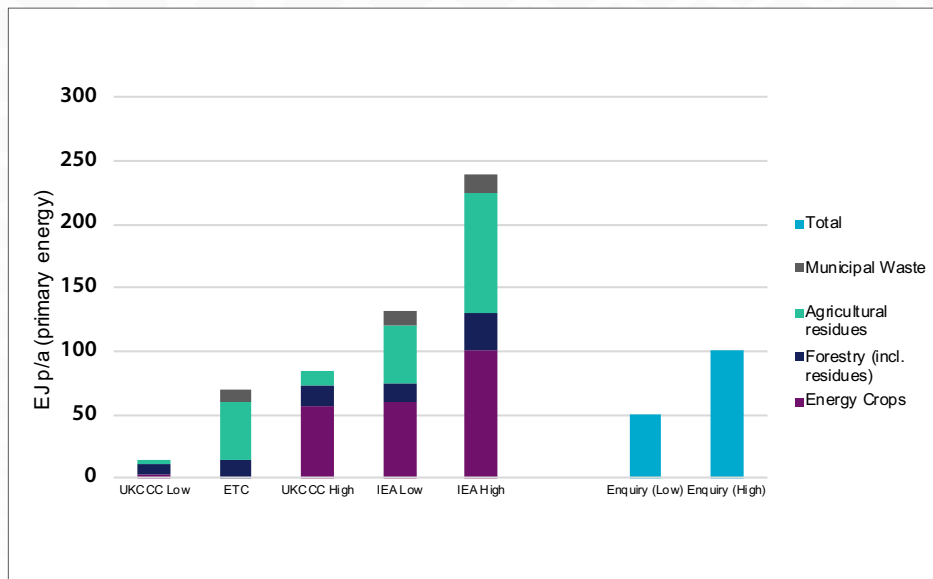


Figure 7: Forecasts for the potential future availability of sustainable biofuels by mid-century (data is in EJ per year)

Source: Figure compiled by Forum for the Future using data from UK CCC, IEA and ETC

The UK CCC's energy crop estimates "assume principally 'second generation' lignocellulosic crops grown on lower quality abandoned farming land, reducing the risk of displacing food production." Its scenarios do not assume any production of biomass from 'first generation' food crops – although the UK CCC does recognise that there may be potential for this to be done sustainably.

The UK CCC recognises, even its high scenario estimate of availability is "at the low end of biomass availability assumed in many global mitigation scenarios that achieve ambitious climate goals." Projections towards 100EJ per year and above assume an enabling environment where dedicating land for energy crops is considered legitimate, and there is a major societal engagement for biofuels to be viable at scale.

The IEA are more optimistic about the potential role for energy crops. Their estimate of the availability of agricultural waste is also much higher than that assumed by the UK CCC. In their research on how the hard-to-abate sectors (including both shipping and aviation) might reach net-zero carbon emissions by 2050⁵¹, the ETC has adopted the IEA's low-end numbers, and excluded the use of energy crops.

In taking this approach ETC state that "70EJ per annum of sustainable biomass for energy and feedstock would be available by mid-century". Had a similar screen to the UK CCC's projections been applied, these figures would have been a more modest 10-27EJ per annum.

Given these uncertainties, our inquiry found that availability rising beyond 100EJ per year to be highly unlikely.

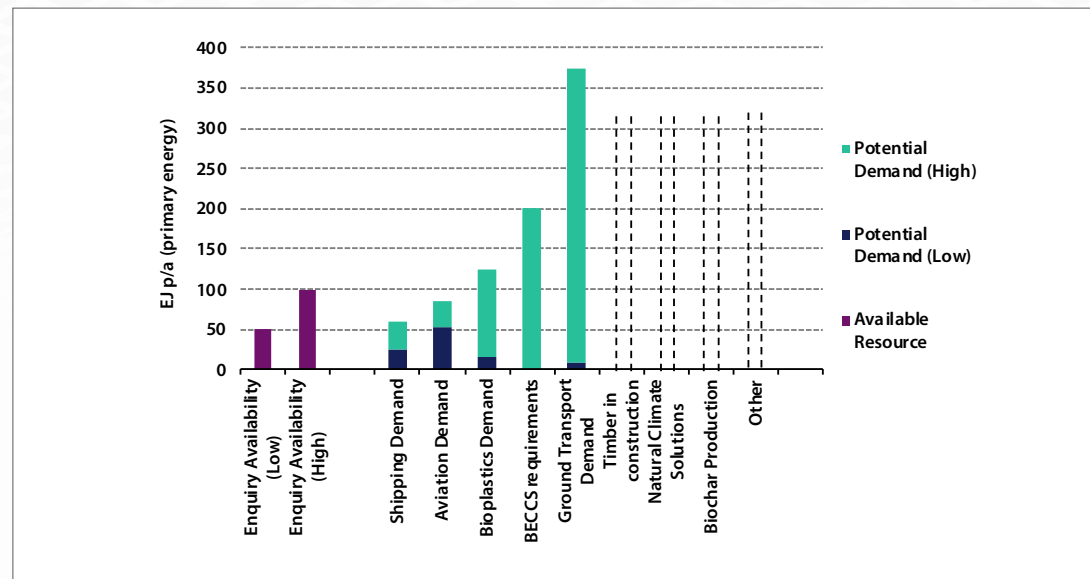


Figure 8: Projected availability of sustainable biofuel (by mid-century) compared to potential demand from a selection of industrial sectors and/or other potential uses of bio-feedstock⁵⁴

Sources. Full description of the sources of these estimates for demand appear in the Appendices. Figure compiled by Forum for the Future using data from ETC; ICCT; ICAO; IPCC; UK CCC; World Energy Council

However, there was fairly wide consensus that 50-100EJ of sustainable bio-feedstock could become available per year by mid-century. This variation in future availability projections is shown in Figure 7.

Availability numbers towards the higher end of this range are much more likely, if purpose-grown energy crops are included, but doing so poses a higher risk of unintended, indirect consequences.

There is also the possibility that energy crops decrease in availability over time. WWF's study exploring the current and future potential of biofuel feedstock production in sub-Saharan Africa⁵² found that the availability of land that could be used for biofuel production would be reduced by about 40% between now and 2050, based on the assumption that future demographic change and improved diets will require some of this land to be converted to food production.

“We need to ask ourselves: how do we ensure that biofuels and alternative fuel technologies are placed in the sectors where they would have the most impact?” -

*Christine Weydig, Director,
Office of Environmental and Energy
Programs, The Port Authority of
New York & New Jersey*



Photo: Colin Clark Photo

3.2 How much sustainable biomass might become available for shipping?

If 50-100EJ per year of sustainable bio-feedstock becomes available across society, it is difficult to assess which sectors to which this would be made available.

Aviation and ground transportation, and non-transportation sectors such as construction and plastics, may also seek to use bio-feedstocks as alternatives to fossil fuels. 50-100EJ per year is insufficient to meet the demand arising from all these sectors.

Shipping's current demand is around 10EJ per year and is projected to grow to some 26-60EJ per year by 2050.⁵³ These numbers are small in comparison to the potential demand from other sectors, as shown in Figure 8.

The simple conclusion from Figure 8 is that 50-100EJ per year is unlikely to be sufficient to meet the demand arising from all potential sectors, and might not even meet potential demand from the aviation sector alone.

The simple conclusion from Figure 8 is that 50-100EJ per year is unlikely to be sufficient to meet the demand arising from all potential sectors, and might not even meet potential demand from the aviation sector alone.

3.3 How might scarcity be managed and governed?

How available bio-feedstock is distributed across the economy will likely be a result of market forces, however a number of authorities state that, as a scarce and valuable resource that could contribute in different ways to the decarbonisation of society, certain sectors could have priority over others.

Ground transportation, given its current demand of 82.5EJ per year, is considered by some stakeholders to be a poor use, in terms of sustainability, of any available bio-feedstock. The CCC, for example, states that “there is no long-term role for biofuels in surface transport (with the possible exception of HGVs) because there are other viable low-carbon options.”

However, they also state that “harvested biomass should generally be used to sequester atmospheric carbon”, meaning that the production of materials is preferable to the production of fuels. At present, this means that using wood in construction could be prioritised, but as innovative bio-based products (such as bioplastics) emerge the CCC notes that this sector could make a strong claim, in carbon terms, on any available bio-feedstock.

Beyond that the CCC states that “should available options for doing this be exhausted... then the greatest abatement would be delivered by using biomass to displace high-carbon fossil fuels where there are no other viable low-carbon alternatives”: for the CCC, this means aviation.

The ETC agrees, stating that: “aviation should have the highest priority claim on limited sustainable biomass resources, given the lack of any feasible alternative to liquid hydrocarbons as the energy source for international flight...shipping represents an intermediate case, with alternative technically feasible routes to decarbonization (e.g. ammonia).”⁵⁶

Both these factors – that potential demand from various sectors is likely to be significantly higher than sustainable supply, and that shipping is considered a lower-priority user for what could be a limited resource – need to be considered in understanding the role sustainable biofuels can play in decarbonising shipping.

4. Findings

4.1 The need for zero-carbon solutions

An emissions trajectory aligned with global efforts to limit warming to 1.5°C would require complete decarbonisation of the shipping sector by mid-century. A revised IMO GHG Strategy in 2023 should provide a regulatory roadmap towards 2050 to offer the maritime industry a degree of certainty to encourage investment in ZEVs, alternative low- and zero- carbon fuels and the infrastructure they need.

Complementing these developments is the Getting to Zero Coalition with its growing membership comprising industry leaders from across the shipping value chain with the ambition that commercially viable ZEVs need to entering the market in 2030.

To meet this level of ambition, biofuels produced from certain feedstocks could be considered to qualify as zero-carbon. For example, some waste-based feedstocks do already qualify according to some measurement methodologies: development of algae as a feedstock or the production of biofuels utilising CCS technologies. Most biofuels – particularly those derived from energy crops – are qualified as lower-carbon, rather than zero-carbon.

The inquiry revealed an expectation amongst particularly environmental stakeholders that alternatives such as hydrogen or ammonia will become the dominate fuel in shipping's fuel mix portfolio, with electric vessels emerging on certain local/shorter routes and biofuels being restricted to existing vessels where alternatives are not cost-effective.

While these solutions may be considered to be zero-carbon as they have no operational emissions, they do require significant investment to ensure they emerge at scale within the timeframes required.

4.2 Shipping might be an 'early adopter' of sustainable biofuel

The challenges identified throughout our inquiry suggest that sustainable biofuels are not likely to be a long-term decarbonisation solution for shipping. Marine fuel specifications are less stringent than other sectors, for example, those of aviation fuel and the aviation sector's planned adoption of sustainable biofuel means there is a risk of end-user driven demand competition. The UK CCC agrees that there are "likely to be other low-carbon options [for shipping] by 2050," however, it recognises that, "there may be a transitional role for some biofuel use."

Further, the availability constraints may not be as challenging if competing sectors take time to scale up their use of bio-feedstocks. For example, a scenario of the lower-end projection for future aviation demand, (about 25EJ per year) would enable both the aviation and shipping sectors to meet 50% of their expected fuel demand in 2050.

"Shipping is not going to solve this alone: Collaboration is key."
- Andrew Stephens



Photo: Colin Clark Photo

4.3 Are aviation and shipping necessarily competitors for limited supply?

The idea that aviation and shipping would be in direct competition for a limited quantity of bio-feedstock was challenged during our inquiry. The processes used to produce high-quality fuels for aviation are likely to also create a number of lower-quality fuels that could be more suited to shipping⁵⁷. Some feedstocks and processes – e.g. pyrolysis of urban organic waste – could be more suited to producing fuels for shipping. A number of stakeholders therefore proposed that rather than being seen as competitors, aviation and shipping could be complementary/ supportive partners in ensuring the development of a sustainable bio-economy.

Marine engines can be fuelled by the low- or high-quality fractions, while aviation requires high-quality kerosene which implies that the shipping sector could have greater potential to drive demand and provide market confidence in the near term. Further, until the aviation and bio-plastic sectors scale up their use, current availability of sustainable bio-feedstock could be used in shipping. This adoption of sustainable biofuels by the shipping sector could help kick-start early action while providing a clear market signal, giving confidence to investors in the bio-economy.

4.4 Investment is needed if sustainable biofuels are to meet the full demand of any sector

Clear market signals and significant regulatory (and societal) support are necessary for sustainable biofuel production to reach the potential described above.

While there is potential to produce sufficient sustainable biofuel, there is a limited amount available today. Therefore, in answering the question on the role of biofuels in shipping, it is worthwhile considering the contribution over an extended time scale, e.g. by asking the question: Is there sufficient availability to make a contribution to reducing carbon emissions over the next decade, rather than a wholesale switch to biofuels in the long-term?

5. Conclusions and Recommendations

Our inquiry process has shown that in determining the role that biofuels might play in the decarbonisation of the shipping industry, it is necessary to consider a wide range of systemic issues:

- the sustainability and availability of a variety of potential bio-feedstocks;
- the potential demand for biofuels – or bio-feedstocks – from other sectors;
- the geographical distribution of potential production and use of biofuels;
- the potential to measure and certify the sustainability of feedstocks;
- the processes of regulating the allocation of biofuels to different industrial sectors;
- the technical potential of alternative decarbonisation technologies;
- lead times for vessel research and development, and design and build.

Not all of these aspects are within the scope of this inquiry which has focused on the potential sustainability and availability of sustainable biofuel. However, using biofuels in shipping will mean the sector needs to engage with a number of global systems such as food production and land governance.

Although biofuels can be used as a drop-in fuel with minor modifications onboard, to make biofuels a reality at scale requires significant restructuring of fuel production, distribution and logistics systems.

Sustainable biofuels are currently available and are starting to be used within shipping, though production remains small compared to their potential. Production would need to scale-up substantially to reach the working assumption on availability of 50-100EJ.

This will require immediate, concerted and proactive action and engagement with a wide range of stakeholders.

In aiming to answer the question of the role of sustainable biofuels in shipping's decarbonisation we identified the following risks and opportunities.

1) The role of biofuels in shipping's long-term decarbonisation pathway

The supply-demand balance under current expert understanding is tight – even if shipping's demand remains within the supply range our stakeholders believed reasonable (50-100EJ). When other sectors' potential demand is factored in, the potential for shipping to meet most or all of its energy needs from biofuels is further constrained.

When asked for their views on the percentage of which shipping's energy needs would be met by biofuels in 2030 and 2050, the majority of stakeholders agreed this would fall in the 10-30% range (those responding with over 50% were outliers). Further, stakeholders anticipated that biofuel use would be higher in 2030 than 2050, implying this is a short-rather than long-term solution.

Given the ratcheting up of climate ambition across society across all industrial sectors, the pool of available bio-feedstock could be limited. Alongside this, other supply constraints raised by stakeholders were that end uses of bio-feedstocks that result in carbon being stored – i.e. in materials opposed to being released through combustion – could further limit the long-term role of biofuels in the shipping sector.



Forum for the Future's Sally Uren moderating at SSI's Climate Week NYC event. Photo: SSI

2) The potential use of biofuels to accelerate early decarbonisation

Industry stakeholders consulted in this inquiry suggested that in the short-term, biofuels could have a significant role to play to accelerate early decarbonisation action. The low end of the supply working assumption of 50EJ could more than meet all of shipping's current energy needs, and currently only 0.25EJ of advanced biofuels are used globally.

There is therefore, a potential window of opportunity for shipping to use sustainable biofuels whilst sustainable bio-feedstocks are underutilised. However, depending on the supply-demand factors, there is uncertainty on the duration of this supply, with some stakeholders suggesting it could last through much of the 2020s.

3) Scaling of sustainable biofuels

To scale the production of sustainable biofuels, market incentives are needed to provide a signal to encourage investment in the bio-economy, putting sustainability and carbon benefits front and centre. Such a signal could come in the form of IMO led short-term policy measures and/or customers demanding and paying a premium for lower carbon supply chains.

Many of the stakeholders we consulted considered sustainability certification to be a pre-requisite in order to give the market confidence in biofuel use. However, not all were convinced that certification could ensure sustainability.

4) Supply-demand balance

There remains no clear consensus on whether there is sufficient sustainable biomass for shipping as well as other sectors. Current understanding suggests that a biomass-based decarbonisation pathway for shipping comes with considerable supply risks and as a consequence also poses risks related to their price.

However, there are scenarios within the working assumption range of 50-100EJ where there would be sufficient supply for shipping. The key assumptions needed to arrive at this relate to high projections for purpose-grown energy crop use; high recovery of agriculture waste residues; road transport to electrify; and a lower to medium demand from biomaterial.

5) Risk associated with the use of biofuels

Irrespective of potential supply-demand constraints, the use of biofuel carries the additional risk of good intentions resulting in perverse outcomes, for example, increasing carbon emissions.

All stakeholders who supported the use of biofuels considered certification to be a prerequisite to ensuring the transparency and sustainability of biofuel supply chains. However, others considered current use of sustainability certification schemes to be insufficient.

One potential option for the introduction of biofuels into the shipping sector is to use bio-feedstocks from waste and residue rather than from purpose-grown energy crops, which our stakeholders deemed a lower sustainability risk. However, if purpose-grown crops are certified using leading sustainability standards and are sourced within regions with strong land governance, carbon and biodiversity credentials, some stakeholders deemed this to have low sustainability risk while others believed it remained high.

6) The role of biofuels and innovation in the shipping industry

There is potential for the maritime industry to play a constructive role in establishing a sustainable bio-economy. Through this proactive engagement the market for sustainable biofuels could develop to facilitate their role in the decarbonisation of shipping and in doing so, it could also support decarbonisation in other sectors.

In parallel, managing the risks of a sustainable supply means continuing to innovate in zero-carbon solutions from all primary energy sources to provide a clearer picture of which options may emerge to contribute to a longer-term solution that is both available, sustainable – and competitive.

7) The need to cooperate with other sectors and players

Shipping cannot solve or manage these risks and uncertainties alone. In order to ensure that a functioning and sustainable bio-economy emerges, coordination and engagement across all interested sectors and the entire shipping value chain (ports, cargo owners, fuel producers, investors, insurers, regulators, etc) is essential. Aviation and shipping alongside other sectors all have a role to play in providing clear market signals and in ensuring that sustainability is central to the production and sourcing of biomass feedstocks.

“A key question for shipping is how to balance the long-term decarbonisation which may well be ammonia-based with short term options such as biofuels. We need to understand better whether biofuels could be a transitional bridge to ammonia, or whether this would result in wasted investment.”

- Lord Adair Turner, Chair, Energy Transitions Commission



Photo: Colin Clark Photo

Recommendations for further work

From this review of sustainability and availability of biofuels for shipping a clearer picture of the uncertainties and risks has emerged. This work has also illuminated key questions where additional work is needed that will advance understanding for the best routes for decarbonisation of the shipping sector:

- As Lord Adair Turner concluded at the panel event during Climate Week in New York: “A key question for shipping is how to balance the long-term decarbonisation which may well be ammonia-based with short term options such as biofuels. We need to understand better whether biofuels could be a transitional bridge to ammonia, or whether this would result in wasted investment.”
- Whether a near term scaling up of sustainable biofuels use makes the pursuit of other technologies easier or harder?
- What the level of risk is from the different crop-based feedstocks for reputational costs for the industry and unintended social, environmental and climate impacts given the various concerns over these sources of biofuels?
- Whether the use of biofuels, even those sourced from only wastes and residues, present a risk given the opposition of some stakeholders?
- When and at what scale and price could other zero-carbon alternatives become available?
- How can the shipping industry and wider value chain act to scale up the supply of sustainable biofuels?
- A deeper understanding of the likelihood around the assumptions needed to ensure enough sustainable biomass for shipping, notably the feasibility of governing purpose-grown energy crops, the feasibility of recovering substantial portions of agricultural waste residues and the likelihood of road transport to electrify.

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Appendices

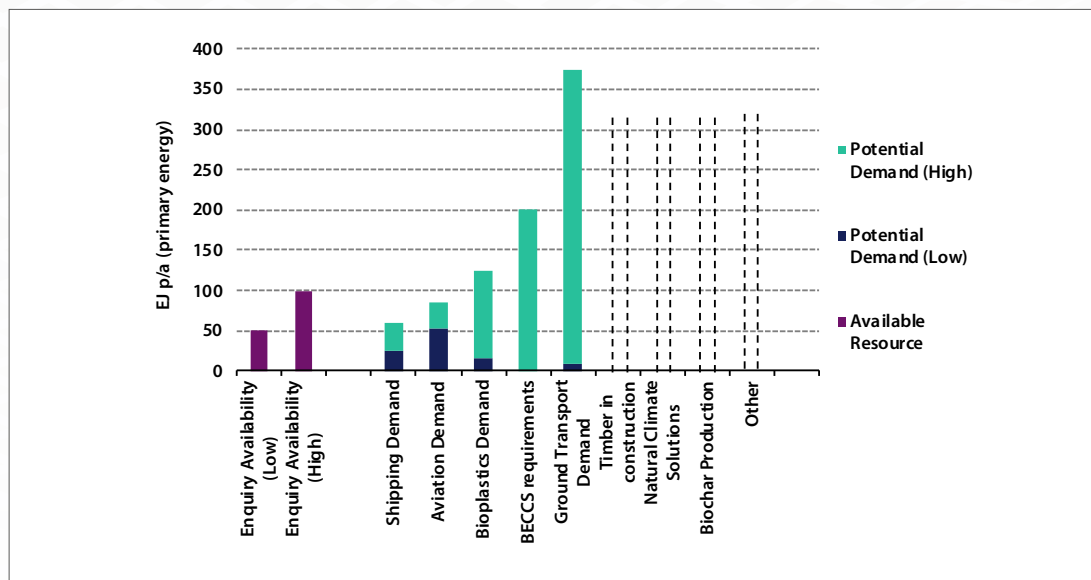


Figure 8: Projected availability of sustainable biofuel (by mid-century) compared to potential demand from a selection of industrial sectors and/or other potential uses of bio-feedstock

Sources: Figure compiled by Forum for the Future using data from ETC; ICCT; ICAO; IPCC; UK CCC; World Energy Council

Sources of estimates for demand

- Shipping:** Low: ETC projects that marine demand could reach 13EJ per year by 2050. Assuming a 50% conversion efficiency in marine biofuel production, this results in some 26EJ per year of primary demand. High: ICCTs project that marine demand could reach 20EJ per year by 2050 (energy in finished fuel) Assuming a 30% conversion efficiency in marine biofuel production, this results in some 60EJ per year of primary demand.
- Aviation:** Low: ETC, citing ICAO, projects that aviation demand will reach 26EJ per year by 2050. Assuming a 50% conversion efficiency in aviation biofuel production, this results in some 52EJ per year of primary demand. High: The UK CCC projects that aviation demand in 2050 could reach 85EJ per year by 2050. This is based on ICAO estimates – but also assumes a 30% conversion efficiency in aviation biofuel production.
- Plastics:** The UK CCC project that bioplastics demand could reach 125EJ per year by 2050. This reflects potential demand “if the full technical potential of bio-based plastics were realised.” Recognising the uncertainties involved, however, it also provides a low-end projection of 15EJ per year by 2050.
- BECCS:** The UK CCC provides a range of BECCS biomass demand based on the different global mitigation scenarios taken from the IPCC Special Report on 1.5C. Some of the IPCC 1.5C scenarios require more than 200 EJ per year to be used for BECCS.
- Ground Transportation:** The World Energy Council’s ‘Hard Rock’ scenario projects that final energy consumption from road transportation in 2040 could reach some 3000 Mtoe per year (the equivalent of some 125EJ per year) . Our high-end figure of 375EJ per year assumes that this demand is met fully by biofuels (which is not the case in the Hard Rock scenario), and assumes a 30% conversion efficiency in road transportation biofuel production. Our low-end figure assumes that road transportation has almost completely electrified, with only small residual demand for biofuels.

Endnotes

- 1 <http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf>
- 2 <http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/GHG-Emissions.aspx>
- 3 e.g. Roundtable for Sustainable Biomaterials (RSB) and International Sustainability & Carbon Certification (ISCC)
- 4 https://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
- 5 <https://www.theccc.org.uk/wp-content/uploads/2018/11/Land-use-Reducing-emissions-and-preparing-for-climate-change-CCC-2018-1.pdf>
- 6 http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf
- 7 <https://www.iea.org/tcep/transport/biofuels/>
The IEA states that “technologies to produce biodiesel and hydrotreated vegetable oil (HVO) from waste oil and animal fat feedstocks are technically mature and provided 6-8% of all biofuel output in 2018.” Their total figure for 2018 is 88Mtoe and using online convertors to MJ and then EJ gave 0.25EJ for 7% of 88Mtoe i.e. 6.16Mtoe.
- 8 is therefore intended to be illustrative, showing how potential demand for sustainable feedstock is extremely likely to outstrip potential supply.
- 9 Full description of the sources of our estimates for demand appear in the Appendices.
- 10 <http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf>
- 11 <http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf>
- 12 [http://www.imo.org/en/OurWork/Documents/Resolution%20MEPC.304\(72\)%20on%20Initial%20IMO%20Strategy%20on%20reduction%20of%20GHG%20emissions%20from%20ships.pdf](http://www.imo.org/en/OurWork/Documents/Resolution%20MEPC.304(72)%20on%20Initial%20IMO%20Strategy%20on%20reduction%20of%20GHG%20emissions%20from%20ships.pdf)
- 13 <https://www.climatechangenews.com/2019/02/12/swedish-shipping-industry-prepares-go-fossil-free-2045/>
- 14 <https://britishmarine.co.uk/News/2019/July/UK-Government-releases-Clean-Maritime-Plan-setting-maritime-zeroemission-travel-strategy>
- 15 <https://www.maersk.com/news/articles/2019/06/26/towards-a-zero-carbon-future>
- 16 <https://newsroom.inter.ikea.com/about-us/all/our-view-on-decarbonisation-of-ocean-freight/s/5a42325a-a182-4140-be8e-30dfd2b0ae7f>
- 17 <https://www.globalmaritimeforum.org/getting-to-zero-coalition/>
- 18 https://www.un.org/en/climatechange/assets/pdf/release_industry_transition.pdf
- 19 https://www.ssi2040.org/wp-content/uploads/2018/05/SSI_ZEV_Report_Final-May-2018.pdf
- 20 <https://www.maersk.com/news/articles/2019/03/22/maersk-partners-with-global-companies-to-trial-biofuel>
- 21 <https://worldmaritimenews.com/archives/272953/cma-cgm-containership-to-test-sustainable-marine-biofuel/>
- 22 <https://www.ds-norden.com/news/news/1543398026.html>
- 23 <https://www.governmenteuropa.eu/hurtigruten-fuel-cruise-ships-fish-waste/91189/>
- 24 https://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
- 25 The consultation process comprised a series of events, including: (i) a seminar on the sustainability of biofuels hosted by SSI member WWF (Brussels, 26 June 2019); (ii) a seminar on the availability of biofuels for shipping, hosted by SSI member Maersk and held at the International Maritime Organization (London, 11 July); (iii) a webinar targeted at Americas-based stakeholders held on 12 August; and (iv) an event at Climate Week NYC with high level panel debating the role of sustainable biofuels in the context of the maritime industry’s transition to zero-emissions shipping. Preliminary findings shared with industry stakeholders at the International Maritime Organization (IMO) during the Symposium on IMO 2020 and Alternative Fuels (17-18 October 2019) and the 6th Intersessional Working Group on the Reduction of GHG Emissions (15 November 2019); as well as the annual meeting of the Roundtable on Sustainable Biomaterials (RSB) (5 December 2019).
- 26 https://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
- 27 <http://highcarbonstock.org/the-high-carbon-stock-approach/>
- 28 <http://naturalclimatesolutions.org/>
- 29 https://wriorg.s3.amazonaws.com/s3fs-public/avoiding_bioenergy_competition_food_crops_land.pdf
- 30 <https://www.ipcc.ch/report/srccl/>
- 31 <https://www.theccc.org.uk/wp-content/uploads/2018/11/Biomass-in-a-low-carbon-economy-CCC-2018.pdf>
- 32 https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf
- 33 https://www.transportenvironment.org/sites/te/files/2019_01_Cerology_Risk_management_study.pdf

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- 34 https://theicct.org/sites/default/files/publications/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf
- 35 https://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
- 36 <https://www.wwf.org.za/wildlife/?27001/Biofuel-production-in-sub-Saharan-Africa-should-be-prioritised-for-aviation>
- 37 http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf
- 38 https://www.ipcc.ch/site/assets/uploads/2019/08/SRCCL_Presentation.pdf
- 39 <https://www.wwf.org.za/wildlife/?27001/Biofuel-production-in-sub-Saharan-Africa-should-be-prioritised-for-aviation>
- 40 <http://rsb.org/the-rsb-standard/about-the-rsb-standard/>
The RSB Standard requires – among other criteria – zero deforestation for bio-feedstock production; safeguards ecosystems of high value for biodiversity; protects cropland needed for current and future food and feed production; ensures water flow in river basins and key wetland areas; and requires that biofuels deliver a minimum of 60% GHG emission savings compared to fossil fuels.
- 41 https://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
- 42 <https://www.iea.org/tcep/transport/biofuels/>
- 43 <https://www.iea.org/tcep/transport/biofuels/>
- 44 Figure derived from IEA numbers that note that biofuel production in 2016 was 79 Mtoe (equivalent to 3.3EJ). Assuming virtually all of this is used in road transport, and that this figure represents 4% of world transport fuel demand, this means that total road transportation demand is 82.5EJ per year.
- 45 http://www.energy-transitions.org/sites/default/files/ETC%20sectoral%20focus%20-%20Shipping_final.pdf
- 46 <https://www.theccc.org.uk/wp-content/uploads/2018/11/Biomass-in-a-low-carbon-economy-CCC-2018.pdf>
- 47 <https://www.nature.com/articles/s41467-018-05340-z#article-info>
- 48 https://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
- 49 <https://www.theccc.org.uk/wp-content/uploads/2018/11/Biomass-in-a-low-carbon-economy-CCC-2018.pdf>
- 50 http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf
- 51 http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf
- 52 <https://www.wwf.org.za/wildlife/?27001/Biofuel-production-in-sub-Saharan-Africa-should-be-prioritised-for-aviation>
- 53 http://www.energy-transitions.org/sites/default/files/ETC%20sectoral%20focus%20-%20Shipping_final.pdf
- 54 Estimates of future demand across different sectors vary considerably, and the sectors which have been quantified above do not represent the full set of sectors, or uses, which might make a claim on bio-feedstocks (as shown in the ‘unquantified columns’). This figure is therefore intended to be illustrative, showing how potential demand for sustainable feedstock is extremely likely to outstrip potential supply.
- 55 Full description of the sources of our estimates for demand appear in the Appendices.
- 56 http://www.energy-transitions.org/sites/default/files/ETC%20sectoral%20focus%20-%20Shipping_final.pdf



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